Tufts University FLARE Scan Study

At the beginning of 2005 the Tufts group, in consultation with Adam Para, started a study of the efficiency and background rejection capabilities of liquid argon detectors.

Analysis was based on a blind scan of 450 events, carried out by 4 undergraduates with additional scanning of “signal” events by experts.

Scanning:

- Events in liquid argon lend themselves to visual interpretation.
- An estimate of what can be achieved with software in the fullness of time
- Through a scan/truth comparison feedback loop even scanners starting from scratch can quickly develop pattern recognition capabilities.
- Can make estimates of signal efficiency and background rejection even in the absence of any reconstruction software.
- No reliance on truth information or parametrized smearing functions.
- Established scanning methodologies based on our experience on previous experiments

Scanning Tools / Sample

Same tools as NOvA simulations

- Neutrino event generator: NEUGEN3. Derived from Soudan 2 event generator. Used by MINOS collaboration. Hugh Gallagher (Tufts) is the principal author.
- GEANT 3 detector simulation: trace resulting particles through a homogeneous volume of liquid argon. Store energy deposits in thin slices.
- LAIR (Liquid Argon Interactive Reconstruction), derived from MAW (Robert Hatcher), derived from PAW.
  - Project energy depositions onto the wire planes
  - Bin the collected charge according to the integration time
  - Ignore (for now) edge effects, assume signals well above the electronics noise
  - Assume two track resolution (2 μs)
  - Event display (2D, 3 projections)
  - Interactive vertex reconstruction
  - Interactive track/conversions reconstruction

(from Adam's Review talk)

Scanner Training

Our scanners were 4 undergrad Physics majors:
Brendan Bowler, Santiago Gangotena, Andrew Hall, and Joseph Wiener spent about 5-10 hours per week over the course of the spring semester.

Training:

1) Intro to neutrino interactions, oscillations, and particles in LAr
2) Intro to the detector geometry / stereo views and event displays. Look at single particles (μ, e, γ) with fixed energy and angle.
3) Scan ~50 events each from ν_e and ν_μ CC and NC samples.
4) Scan ~50 event samples of mixed NC and CC events and check results against truth
5) Repeat step 4 a few times with varying amount of input from "experts" (Gallagher and Schneps)
6) Scan several dozen events from "hard" samples. y>0.8 CC events, NC events with 3 or more π^o.

Scan Methodology

Methodology of the “double blind” scan similar to that used in Soudan 2.

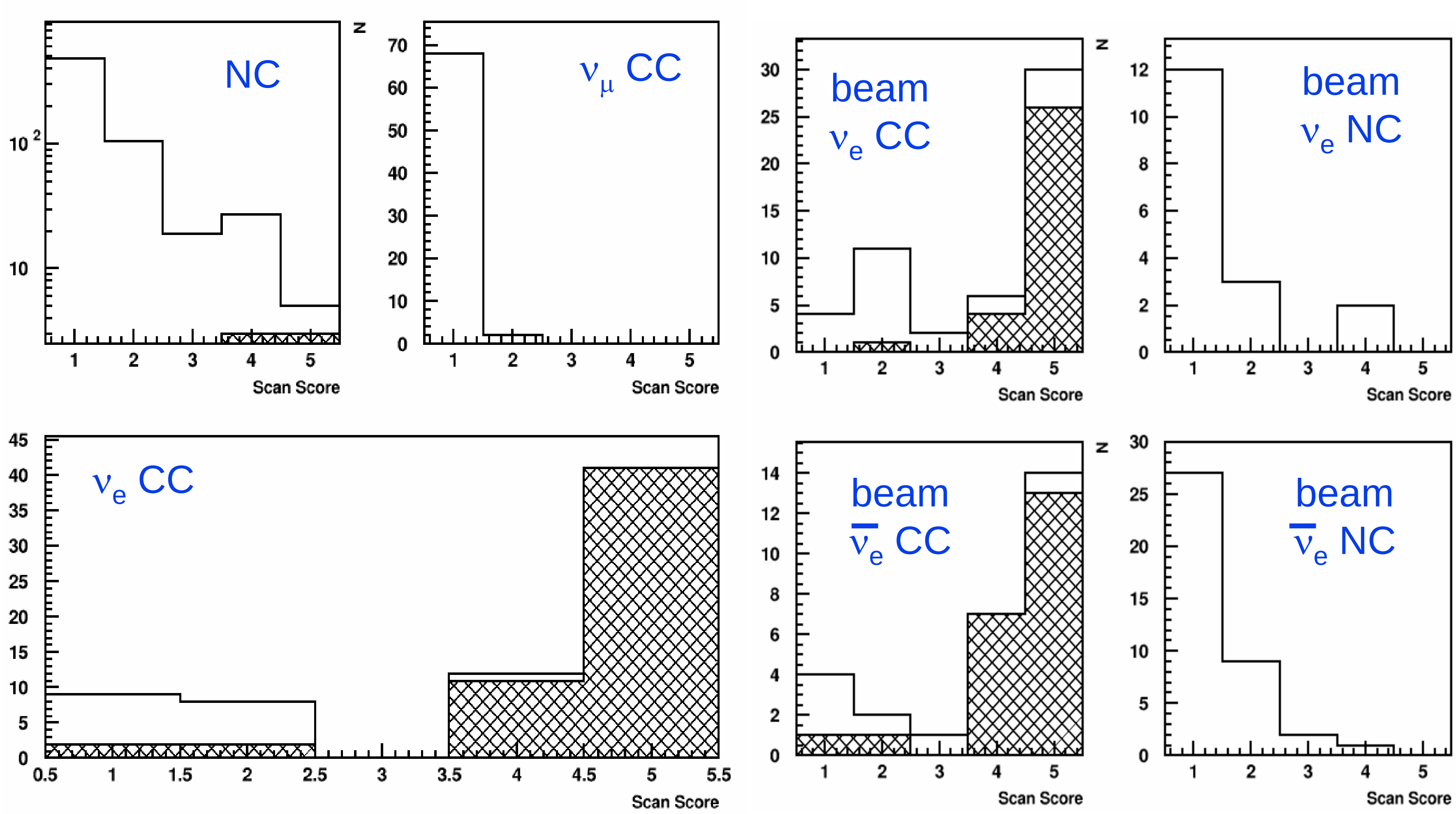
Each event is scanned independently by two students, and graded on a scale of 1 (background) – 5 (signal). Truth information is not accessible. 450 events scanned.

For any events where the scores disagree by more than one unit, the students meet as a group to discuss the event and try to reach a compromise score.

Particularly difficult events or those which cause intractable dispute are passed up to the “experts”. Experts also scanned every event which at least one student had given a 3 or higher. Experts scanning done by at least 2 of Gallagher/Mann/Schneps.

One student is assigned to “reconstruct” each event. Using the scan / graphical reconstruction package developed by Adam and others they assign a vertex to each event, and assign points in space which serve to identify each of the particles emerging from the primary vertex. Each particle is identified as shower-like, neutral, non-interacting, etc. → input to subsequent analysis software (future work)

Scan Decisions (2 per event)



Correlations in Scan Decisions

Students scan decisions were highly correlated.

NC Background:
282/290 within one unit

SCANNER 1 (columns) / SCANNER 2 (rows)

	1	2	3	4	5
1	*202*	*24*	*0*	*1*	*0*
2	*24*	*15*	*3*	*1*	*1*
3	*2*	*2*	*1*	*3*	*0*
4	*1*	*1*	*2*	*4*	*0*
5	*0*	*0*	*0*	*2*	*1*

Signal ν_e:
27/32 within one unit

SCANNER 1 (columns) / SCANNER 2 (rows)

	1	2	3	4	5
1	*2*	*0*	*0*	*0*	*0*
2	*1*	*2*	*0*	*1*	*1*
3	*1*	*0*	*0*	*0*	*0*
4	*1*	*1*	*0*	*5*	*0*
5	*0*	*0*	*0*	*3*	*14*

1. Students were applying similar rules
2. Topological features were clear for most events

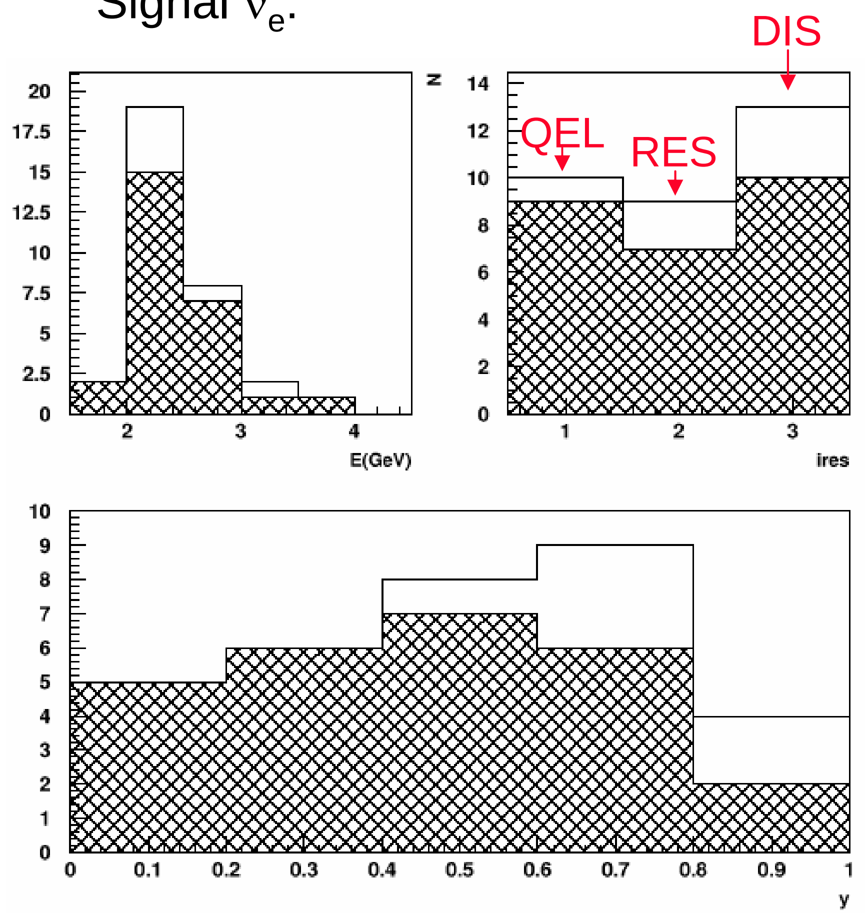
Results

Results:

	N	pass	ε	η
NC	290	4	-	72.5
signal ν_e	32	26	0.81	-
Beam ν_e: CC	24	14	0.58	-
NC	8	0	-	
Beam $\bar{\nu}_e$: CC	13	10	0.77	-
NC	19	0		
ν_μ CC	32	0	-	?
$\bar{\nu}_\mu$ CC	32	1	-	?

Of the 32 signal events, 27 passed through the student scan.
1 rejected in the expert scan
2-3 of the failed 5 might be OK

Signal ν_e:

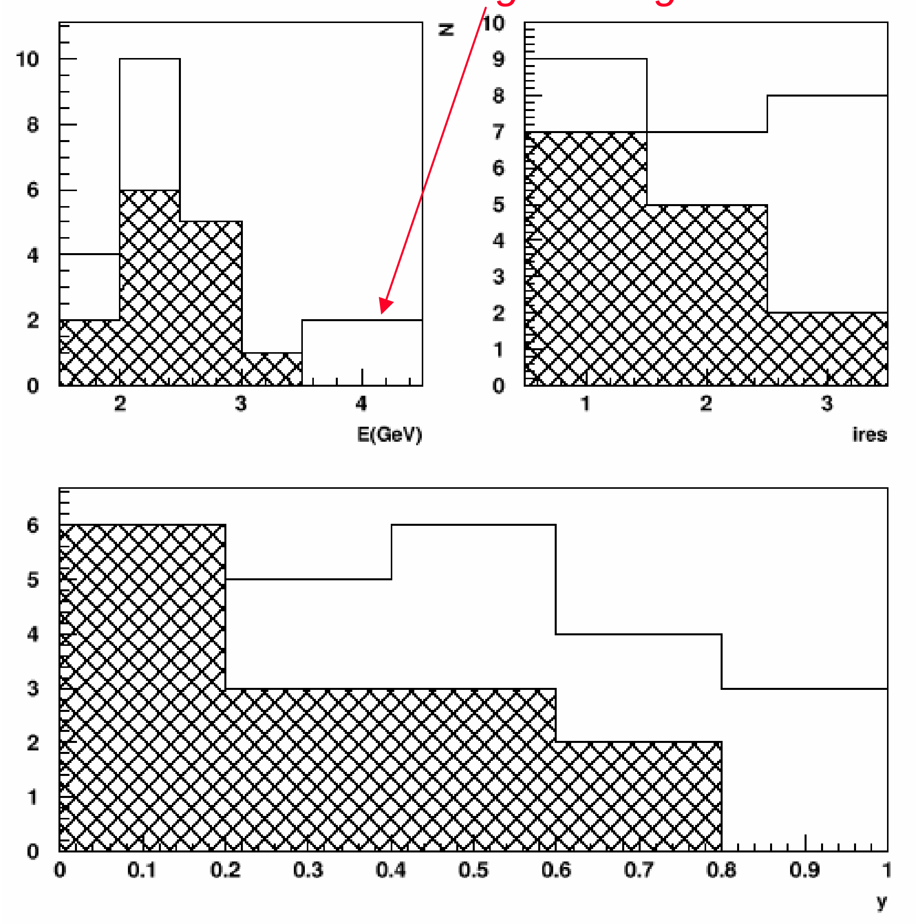


FOM approximately 2 times NOνA-I

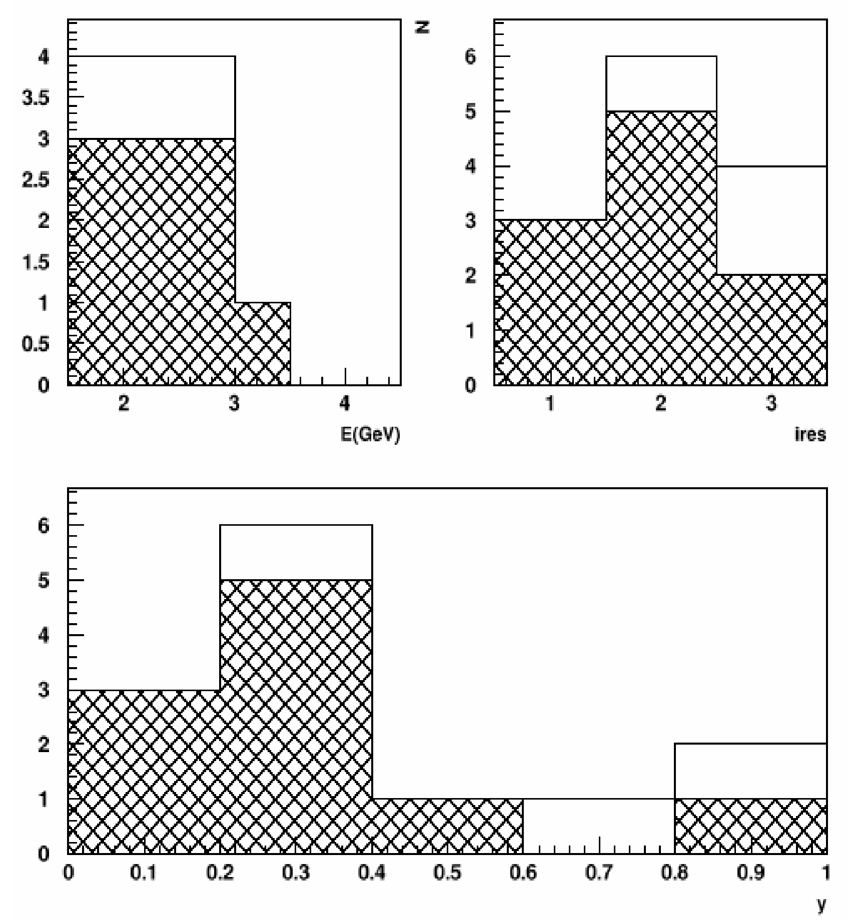
Results

Training bias against high E?

Beam ν_e:



Beam $\overline{\nu}_e$:



Decision Procedure

Identify Vertex

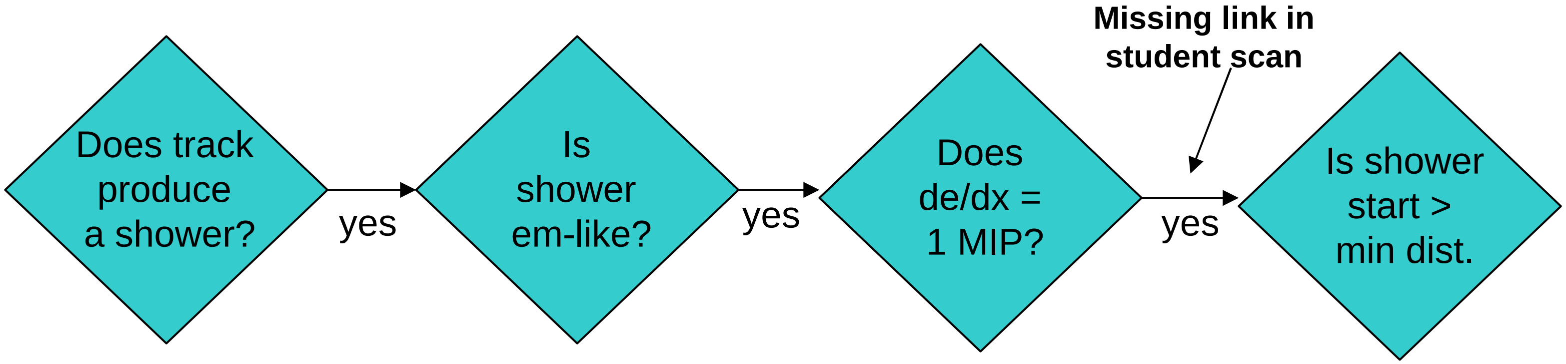
Identify tracks coming from vertex
in each view

Correlate tracks in
3 views of event

Identify em showers (each view)

Correlate em showers
in 3 views

For each track:



Decision Procedure (software)

Identify Vertex

Assume truth

Hough Transform

Identify tracks coming from vertex in each view

iterate

Identify em showers (each view)

Correlate tracks in 3 views of event

Correlate em showers in 3 views

Stereo geometry

For each track:

em-shower identification

Does track produce a shower?

yes

Is shower em-like?

yes

Does de/dx = 1 MIP?

yes

Is shower start > min dist.

Road/ shower finding